A Laboratory Development and Networking Concept for Naval Aviation

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Abstract

This paper presents a concept for laboratory utilization and networking in support of avionics systems development and integration for Naval Aviation. The Naval development centers for air systems have a number of separate laboratory facilities that deal with the many facets of avionics systems in Navy airborne platforms. The laboratories associated in developing and implementing this concept are those located at the Naval Air Warfare Centers (NAWCs) at Patuxent River MD, China Lake CA and Point Mugu CA. The purpose of exploring and then implementing this concept is to ensure that the Navy makes maximum use of the laboratory resources available, and through networking, provides a capability for multiple center participation in shared program developments.

The effort underway is embodied in two elements: Modular Avionics Integration Laboratory (MAIL) and Modular Avionics Integration Network (MAIN). The MAIL element is concerned with the identification and networking together, laboratory resources within the confines of a single development center. The MAIN concept is a networking approach for linking the three centers so that inter-center participation can be achieved for broad scope systems development and integration programs. Taken together, the MAIN and MAIL represent a forward step towards implementing a consistent systems engineering based process for avionics systems evaluation, development and integration for the Navy.

1.0 Introduction

In the current era of downsizing, the tendency is to examine every resource for its value to the enterprise. Resources of the Naval Air Systems Command (NAVAIR) "Naval Aviation Systems Team" are continually being assessed and evaluated to determine whether value added (often measured as return on investment) merits their retention. Over

the years, the Navy has acquired numerous laboratory elements widely dispersed throughout the many facilities that support the NAVAIR Team. Generally, each of these separate laboratory elements has a special, often unique, function that is important to Naval aviation. Taken together these laboratory elements comprise an important national resource. MAIN/MAIL is a concept for enhancing and ensuring full utilization of the existing laboratory facilities throughout the Naval Aviation Systems Team community.

Modular Avionics Integration Laboratory (MAIL) describes a laboratory utilization approach focused on resources contained within a single Navy development center. Typically any networking done to support MAIL is accomplished by and within the range of a local area network (LAN). The Modular Avionics Integration Network (MAIN) extends the overall functionality of the MAIL concept by adding a networking capability to link Navy development centers that are hundreds or thousands of miles apart. The MAIN/MAIL concepts, taken together, create a broad basis for more effective utilization of existing laboratory resources on a full enterprise basis.

2.0 MAIN/MAIL Structure and Organization

The original organization structure for MAIN/MAIL consists of the NAWC Aircraft Division and NAWC Weapons Division development centers under NAVAIR, Avionics Department leadership. It is expected that as the concept is implemented and further evolves that other facilities (such as the Depots) will be integrated into the system. The fundamental organization is shown in Figure 1.

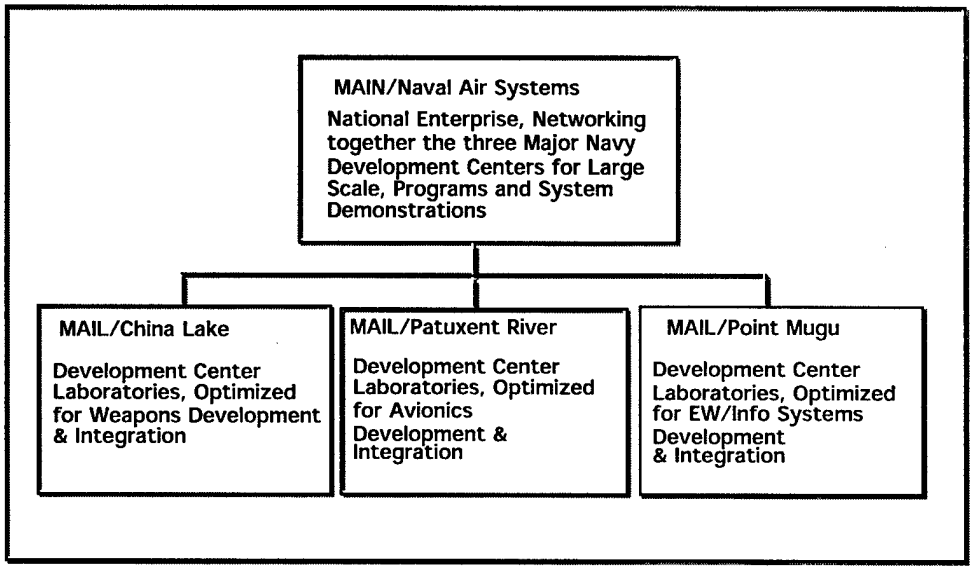

Figure 1. The fundamental organization of MAIN/MAIL

Figure 1 presents an organization that utilizes the fundamental functional work break down structure (WBS) that exists in the resources of the Naval Air Systems Command in establishing MAIN/MAIL. As shown, at a top level, China Lake is primarily responsible for weapons technology, weapons development and weapons integration. Patuxent River is primarily responsible for avionics technology and avionics systems concepts development.

Point Mugu has primary responsibility for electronics warfare and information systems technology and EW/IS systems development. This is a topdown, work breakdown, and generally true although elements of some of the major functional areas exist at other than the principal development center. The starting point for the MAIL at each of the development centers is to provide a laboratory system to support the development of key supporting technologies and their transition to operational systems. The laboratory is configured to support system development and developmental testing and evaluation. Each MAIL is intended to primarily support the functional/ technology area as defined locally at each of the participating development centers. The areas of technology specialization are shown in Table 1. The Avionics Department S&T Program (AIR-4.5T directed) Maritime Aviation Subsystems and Technology (MAST) Program has an identified focus for avionics technology and architecture research and is primarily administered and performed at Patuxent River MD. Each of the other Centers receive funding in the technology areas identified.

Navy Center	Technology Area
China Lake, CA	Weapons, Weapons Integ.
Patuxent River, MD	Avionics, Core Processing
Point Mugu, CA	Electr. Warfare, Info Sys.

Table 1. Technology Emphasis Areas at Navy Air Warfare Centers

The first purpose of each MAIL is to provide a facility to demonstrate and exercise products from Navy S&T initiatives in the technology areas assigned. It is expected that this utilization will help to make S&T developments more meaningful and facilitate effective technology transition. Additionally the MAILs serve as entry points for demonstrations of prototype technologies and systems (often proprietary) to the Navy. The MAILs also can serve as development testbeds for Cooperative Research And Development Agreements (CRADAs) and other joint development efforts with Industry, NASA, DARPA and the other military services in an attempt to broaden the business base for more effective utilization of Navy laboratories.

2.1 Networking between Centers: MAIN

The MAIN concept unifies the laboratory resources of the three Development Centers by providing effective networking between the individual MAILs. MAIN provides additional fidelity by making all resources: simulations, laboratory tools, etc. available for large system demonstrations and feasibility experiments. MAIN will utilize the network capability of the Defense Research Engineering Network (DREN), Naval Aviation Wide Area Network (NAVWAN) and other telecommunications links as needed. Although the distance between centers adds data latency issues, pseudo-realtime experiments can be conducted to evaluate basic feasibility for many systems problems. Figure 2 Illustrates the basic networking configuration envisioned.

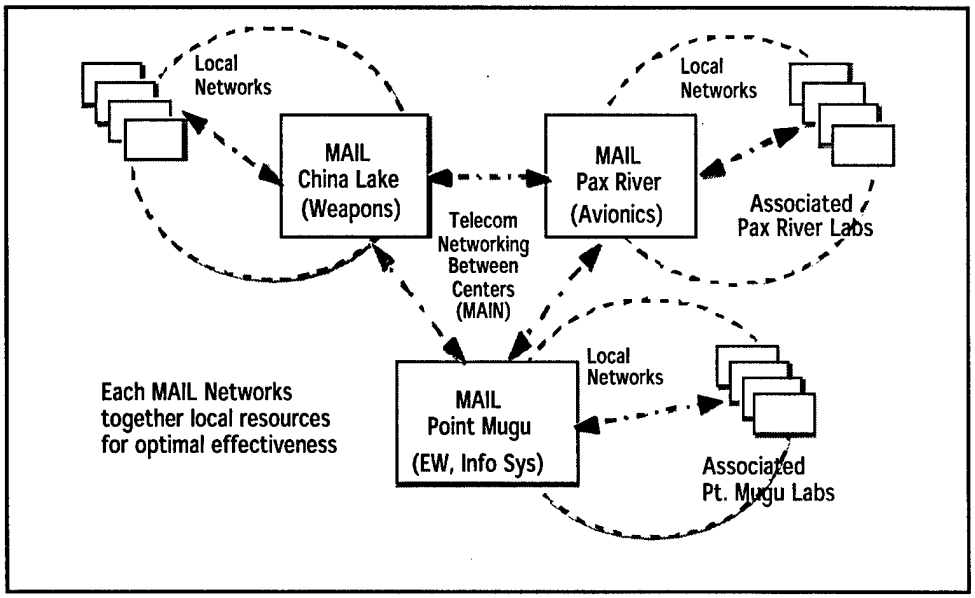

Figure 2. MAIN Networking between Navy Centers for Effective Laboratory Integration/Resource Sharing

Figure 2 presents a basic interconnection diagram. As the network evolves and the business basis expands, additional linkage to Navy Depots, Joint Service and Industrial sites is likely. The "network centric approach to warfare now being pursued is equally valid for the exploration, development process for weapon systems [1]. As conceived, each of the Centers would establish a "centerwide" MAIL to link local laboratory facilities as appropriate to satisfy technological and architectural needs within its areas of expertise. This local networking will utilize existing resources to the maximum extent possible, adding new facilities only as a last resort if needed to achieve overall capability.

2.2 MAIL/MAIL Leadership

AIR-4.5 has taken the leadership role for development of the MAIN/MAIL initiative. As the Avionics Department, AIR-4.5 is responsible for providing the engineering support to program offices responsible for the development and full life cycle support of avionics systems. This responsibility includes setting the policies for Navy avionics systems and assuring that the engineering disciplines required for the avionics "competency" are properly trained and available to the avionics program offices. The actual development and

acquisition activities are the responsibilities of the program offices that develop avionics systems and the platform program offices that utilize these avionics in aircraft and airborne platforms. However, these program offices of necessity must focus on a specific development. Overall avionics policy, avionics systems engineering procedures and processes, consistent avionics architectures and commonality/affordability approaches on a macro level are the responsibility of the avionics competency, AIR-4.5. To accomplish its mission, AIR-4.5 has initiated the MAIN/MAIL Program as a first step towards full integration of its laboratories into an effective National asset for avionics leadership for the Navy. Coupled with the laboratory network integration plan is an expanded business concept that embraces shared development activity with the Tri-Services, DARPA, NASA and Industry (both commercial and military).

Air-4.5 leadership believes that network based laboratory integration similar to that proposed will naturally occur over time on an ad hoc basis. MAIN/MAIL is a program to accelerate this process and assure that network integration is properly planned and effectively implemented.

2.3 The MAIN/MAIL Enterprise Team

A MAIN/MAIL Team has been formed to provide direct "hands-on" management of the concept development and implementation process. The Enterprise Team lead is William H. Schibler of AIR-4.5T. Other principal members are from each of the participating Navy Centers. Additionally, numerous others from involved focus laboratories, experts on networking and other technologies important to MAIN/MAIL are included on the Team. A considerable amount of work has taken place. Team meetings have been held at each of the participating NAWCS and through frequent Video Tele-Conference (VTC) status reviews. Many of the meetings have been held in parallel with laboratory tours to provide a more in-depth understanding of the many individual laboratory resources. Initial work of the Enterprise Team centered around the identification and classification of the many laboratory elements. A database describing each of the individual laboratories has been assembled as a starting point for implementation.

3.0 The Need

The underlying requirement for MAIN/MAIL is to provide a multi-functional avionics development and integration laboratory across the NAVAIR Avionics Department, AIR-4.5. The Avionics Department "competency". The MAIL provides an enhancement of the "core"laboratory capability in support of Navy Air program offices and Joint Service program offices. The flexibility and reconfigurability offered by MAIN/MAIL networking will complement the capabilities of existing laboratory resources and provide a "value added" to their utilization. The functional requirements for a laboratory system are somewhat volatile, changing in response to new, emerging, technologies and system architectural trends. Recent trends in systems engineering have emphasized the use of rapid prototyping techniques to synthesize and evaluate systems concepts more quickly and affordably. These trends and emphasis areas place great value on the versatility and reconfigurability that inter-laboratory networking provides.

At a top level, the mission for MAIN/MAIL can be summarized by the following key elements:

- Provide a framework to demonstrate and transition new technologies into current programs
- Provide a facility to support joint service programs, cooperative research and development projects with Industry, and shared initiatives with NASA, DARPA and others
- Support programs to develop advanced avionics architectures and systems concepts through Enterprise level S&T initiatives and investigations
- Serve as a resource to exercise and evaluate open systems standards and commercial off-the-shelf (COTS) products as candidates for Naval avionics systems and architectures
- Provides a "hands-on" capability for training of scientific and engineering personnel of the Avionics Department.
- Linking of the laboratory resources of the NAWCs and other NAVAIR facilities provides a structure for moving toward a common systems engineering process across the entire enterprise

Each of these key elements is discussed below:

3.1 A Framework to Transition S&T Products

Navy S&T programs are often criticized for failure to effectively transition S&T research into advanced development programs leading to in-service operational systems. Technology transition is difficult at best for a number of reasons. Workload and scheduling problems pose a major barrier to effective technology transfer. Program Offices find it difficult to make key personnel available to travel far and wide to attend S&T technology reviews. Further, it is often difficult to assess the risk involved with a new technology without significant additional evaluation. As a result, potentially useful technologies are often omitted because credible risk versus benefits assessments are not available. On the other side of the equation, those engaged in Navy S&T planning and administration have little budget or time available to engage in full scale marketing to and coordination with the potential user PMA community. As a result, much of the S&T activity is out of phase with program office needs in both content and timing. Recently there have been several efforts to provide better coordination between the S&T community and Naval Aviation Program Offices. Notable among these are the efforts of the Strike Vision Design Team (SVDT), established jointly by the Office of Naval Research (ONR) and the Naval Aviation Science & Technology Office (NAVSTO). Through joint efforts of members of the SVDT and the F/A-18 Program Office a process designated as the Advanced Technology Review Board (ATRB) process has been developed to identify and prioritize high payoff S&T programs [2], [3]. These efforts have been pointed towards a more effective, high payoff Naval research S&T program, coordinated with and integrated into the applicable PMA program roadmaps. The ATRB goal was to improve the ability of the Program Manager to implement emerging technologies in his platform. The ATRB process was originally developed by the SVDT in coordination with the F/A-18 Core Avionics Integrated Product Team (IPT). The process was first utilized by the F/A-18 PMA in 1997. A feature of the work done was that S&T products and continuing parallel S&T development efforts have been incorporated into the "outyears" of the F/A-18 roadmap, far beyond that done previously. To establish a much higher probability of effective technology transfer, the ATRB process has been extended to other programs and is currently being utilized for

S&T transition planning for PMA-201, Conventional Weapons [4]; and PMA-209, Air Combat Electronics. Information gathered using this process will be used as a basis for technology planning for the ONR/AIR-4.5T Maritime Aviation Sub-Systems & Technology (MAST) Program.

In addition to the improved efforts to coordinate S&T efforts with the needs of the PMAs, another problem encountered is that of achieving suitable exposure of advanced technologies and systems concepts to the appropriate PMA decision makers. It is expected that MAIN/MAIL can help to solve this problem. By providing laboratory facilities to demonstrate and showcase new technologies over an extended period of time, effective exposure to potential "customer" PMAs is much more likely to occur. Further, the MAIN/MAIL system can be used to perform the risk assessment versus benefits comparisons needed to justify the use of the subject technologies and/or systems. Long term usage of the MAIN/MAIL to host the products of S&T research, can so permeate the transition process that future S&T projects can be tailored to provide products to demonstrate in the laboratory. An extension of this concept can be used to assure that the products of S&T research are architecturally compatible and complementary to previous and parallel efforts. Consistent use of MAIN/MAIL can result in increased focus of S&T efforts so that the tendency is to create architectural structures that blend the key emerging technologies into effective systems.

3.2 A facility for an Expanded Business Base

Initial business planning for MAIN/MAIL has identified a number of potential customers for an expanded business base. Initially, it is expected that the business utilization for the laboratory resources from traditional customers will increase due to the added capability, architectural flexibility and increased fidelity provided by the networking provided. Additional business areas include the following:

- Integration/Development laboratory for PMAs; Emphasize commodity PMAs that do not currently have a core laboratory facility

- Increase in Programs that are shared between NAWC, Aircraft Division and NAWC, Weapons Division through use of the MAIN networking capability

- Provide a facility/capability to support key Navy IRAD programs

- Expanded participation in Multi-Service Joint programs

- Coordinated Programs with other Government Agencies; promote expanded efforts with NASA, the Defense Advanced Research Projects Agency (DARPA), FAA, et al

- Increased joint government/industry developments. Expand programs conducted under Cooperative Research and Development Agreements (CRADA), and Small Business Innovative Research (SBIR) initiatives.

3.3 Enterprise S&T Initiatives

The MAIN/MAIL laboratory resource provides a base for hosting Naval Air Enterprise S&T initiatives. Such initiatives become important when the Navy needs to evaluate a promising systems concept, but isn't certain of its overall value and hasn't any experimental basis on which to fully define the system requirements. In such instances the Navy isn't prepared to contract for an industrial development and needs an arena for experimentation and evaluation. Typically such enterprise projects involve a number of disparate technologies and system techniques, require multi-disciplinary skills and are larger in scope than the typical in-house S&T project. MAIN/MAIL can be utilized to host such focused enterprise programs and allow Navy engineers and scientists to determine the value and ultimately the requirements for such systems. One illustrative example might be to try out in combination a number of experimental Situation Awareness (SA) enhancing techniques that haven't been experimentally evaluated against Naval crewstation needs. The scope of the project could involve measurement of workload and situation awareness for different combinations of enhancement techniques, measured against Navy specific flight scenarios. A project of this scope could utilize rapid prototyping tools, pilot-in-the-loop (PITL) simulation and advanced processors and display generation equipment. The multi-disciplinary nature of the task would require a widely diverse Integrated Product Team (IPT) which would include human factors specialists, experienced pilots to participate in the evaluations, display and processor engineers and system development/rapid prototyping specialists. The product evaluations and any subsequent requirements generated can be explicitly tailored to Navy needs. The experience gained in projects of this type can provide valuable experience to the Navy practitioners involved and contribute to a more experienced, professional approach to any subsequent contractual development for integration into an operational platform.

3.4 Support for Standardization Activities

MAIN/MAIL provides a capability to support Naval aviation participation in avionics and electronics systems standardization initiatives. It is important if Open Systems Standards are to be effectively utilized that Navy personnel participate in standards development organizations and assure that the needs of Navy avionics systems are incorporated as standards are prepared, reviewed and revised. Key commercial standards organizations such as the Institute of Electrical and Electronic Engineers (IEEE) and the Avionics Systems Division (ASD) of the SAE are particularly appropriate. Figure 3 diagrams the standardization process that is appropriate for the needs of military avionics systems.

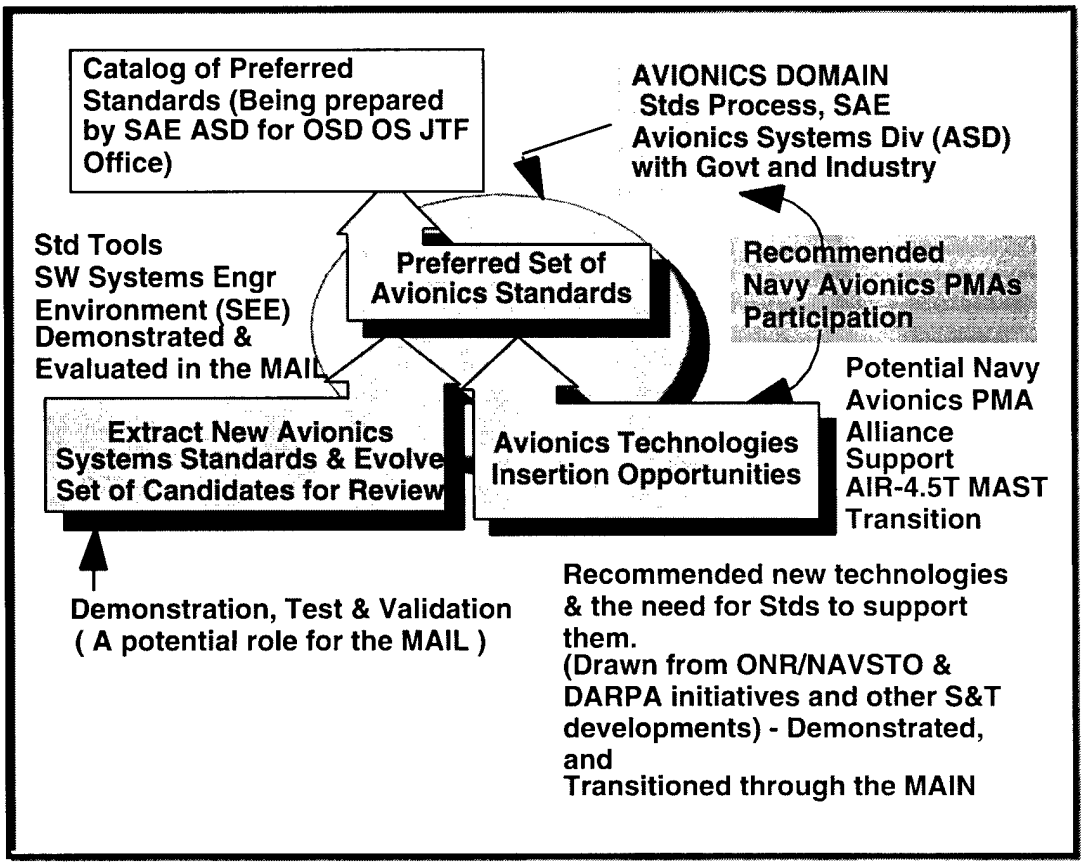

Figure 3. The Standardization Process and the role of MAIN/MAIL in Supporting a Navy role in Avionics standardization

As shown in Figure 3, standardization is achieved by selecting and supporting a system compatible set of avionics systems standards. The selection process, extracts systems interface standards from current avionics and includes them in a set of preferred standards. Figure 3 illustrates the process currently being employed by the SAE Avionics Systems Division in support of the DoD Open Systems Joint Task Force (OSJTF). ASD has been chartered to create a catalog of standards to populate the OSJTF Avionics Standards Domain. As shown in the figure, the standards are continually being updated as new requirements for avionics systems are defined and as new technologies are introduced. As shown in the Figure, it is expected that the Avionics Department, AIR-4.5 would participate in the review of standards and participate in the committees that develop and revise existing standards. MAIN/MAIL is viewed as a major supporting tool for this process, by providing the training that qualifies Navy representatives to participate in the standardization process. MAIN/MAIL also provides a test bed for evaluating Open Systems and/or COTS standards.

3.5 Training basis for utilization of MAIN/MAIL

Under AIR-4.5 leadership, the MAIN/MAIL can be utilized for "hands-on" training with avionics systems. Coordination among the three centers can assure that a cadre of in-house experts in all of the elements of avionics/airborne electronics will have laboratory facilities to maintain their expertise. Availability of MAIN/MAIL will support the effective transfer of expertise from senior technical personnel to new replacement personnel.

Future technical training can emphasize a "hands-on" knowledge of emerging technology by demonstrating new technologies directly in the laboratories. It is expected that "lessons learned experiences" gained through utilizing the MAIN/MAIL will be accumulated and provided as lessons learned for future training of avionics engineers and scientists.

3.6 Support of a Common Systems Engineering Process

MAIN/MAIL provides a framework for the development and implementation of a common systems engineering process throughout the Naval Air Systems Command laboratories. The integration process to prepare the laboratories to communicate and work together under MAIN networking, requires some focusing on standard interfaces, standard tools for requirements definition and analysis, and standardization of development processes. AIR-4.5 shares responsibility for avionics processes, and architecture definition with the Program Offices as part of its Avionics Competency responsibilities. A goal of AIR-4.5 is to achieve a greater degree of unity throughout the Avionics Competency. Joint participation of both NAWC, Aircraft Division and NAWC, Weapons Division in the development and implementation of a common systems engineering process will be a step forward in achieving greater national unity.

Systems Engineering Process Standardization

AIR-4.5 has prepared a set of reference guides/handbooks for systems engineering, computer resources, and other key avionics elements. It is proposed to use the existing handbooks as a starting point and enhance with specific documentation utilized at each of the centers. MAIN/MAIL provides an opportunity to unify the three centers through shared consideration and documentation of standard systems and software engineering process.

Standard Tools

A compendium of standard computer based systems and software-engineering tools will be pursued. Default standards, tools that are identified with certain elements and phases of the systems engineering processes will be identified and considered for adoption throughout the MAIN/MAIL laboratory elements. The goal is to unify the separate centers and systems engineers through common tools and common understanding of the tool utilization.

4.0 MAIN/MAIL Functions

The basic functionality of the MAIN/MAIL system is to provide a technology/systems demonstration facility with a rapid prototyping capability. The laboratory system is utilized for proof-of-concept and risk reduction studies and evaluations. Through its networking capability, the laboratory provides a great deal of flexibility and reconfigurability. Using networking, laboratory elements can be selectively chosen to create a laboratory architecture

that is consistent with the architecture of the system or system concept under development and/or evaluation. The complement of tools and resources necessary to satisfy the functional requirements of MAIN/MAIL include the following:

- "Hot Bench" capability to host prototype systems
- Architecturally broad, Proof of Concept test bed, Achieved by networking of various simulation, stimulation, and hardware in the loop resources
- Provide a Software/Systems Engineering Environment to support system development and integration.
- Necessary instrumentation and software based tools to support diagnostics and systems engineering functions

5.0 Definition and Implementation of MAIN/MAIL

Under direction of the MAIN/MAIL Enterprise Team, planning and early implementation has begun. Progress on definition and implementation of the MAIN/MAIL concept consists of a number of elements as described below.

5.1 MAIL Networking, Aircraft Division

Initial work at Patuxent River has identified the following candidate laboratories for a first phase linking under the MAIL concept:

• Mission Computers & Processors Lab	• Advanced Software Technologies Lab
• IR Systems Evaluation Facility	• Image & Signal Processing Lab
• Surveillance Radar Lab	• Crew Technology Lab, Sim. Facility
• Information Fusion Lab	• SAR Processing Lab
• EO Sensors Lab	• IR Project Spaces
• IR Engineering Lab	• Tactical Radar Exploitation Lab
• Crew Technology Lab, Mission Control Ready Room	• Air Combat Environment T&E Facility (ACETEF)

Table 2. Initial List of Resources for the Patuxent Aircraft Division MAIL Network

The laboratories listed in Table 2 are the initial candidates for MAIL networking at Patuxent River. These laboratories were selected because they are key in exploring advanced technology and system architecture development. The broad diversity of this set of laboratories suggests the many architectural variations that are possible as the laboratories are selectively interconnected on a project by project basis. The same sort of diversity exists at China Lake and Point Mugu as well adding numerous other technologies and system emphasis areas. At Patuxent River, a number of initial demonstration projects have been planned, utilizing a number of the laboratory resources identified in Table 2. Additionally, discussions are underway to link the facilities at St. Inigoes, MD to the Patuxent River laboratory and simulation resources and ultimately through MAIN/MAIL networking, to other laboratory and simulation resources at China Lake and Point Mugu.

5.2 Air Interoperability Center

At NAWC, Aircraft Division, Patuxent River, MD, the Air Interoperability Center (AIC) Project provides an infrastructure resource for linking together many key S&T laboratories and test facilities to better leverage their collective capabilities. The hub of this network is the Air Combat Environment T&E Facility (ACETEF), a tri-service DoD funded Installed Systems Test Facility that serves as the focal point for ongoing programs such as Joint Strike Fighter and Joint Theater Missile Defense. The AIC project consists of two key phases:

Phase 1. An ongoing MILCON-based task to install miles of high-capacity "blown" fiber optic cabling around the Patuxent River complex. The entire cable plant is certified as a "Protected Distribution System" (PDS) to allow the routing of classified scientific & engineering data between key facilities and buildings without the use of cryptographic equipment.

Phase 2. An extensive application development task to provide AIC application support for ongoing and new programs, leveraging the new PDS fiber optic system infrastructure. Efforts of the MAIN/MAIL team are being coordinated with the AIC project team in order to make maximum usage of AIC networking. Figure 4 provides a conceptual view of the AIC backbone network and its utilization to interconnect the laboratory resources of MAIL with other resources at Patuxent River. Figure 4 also indicates the external networking interfaces of AIC, which will be utilized by MAIN for interconnection outside the Patuxent River complex.

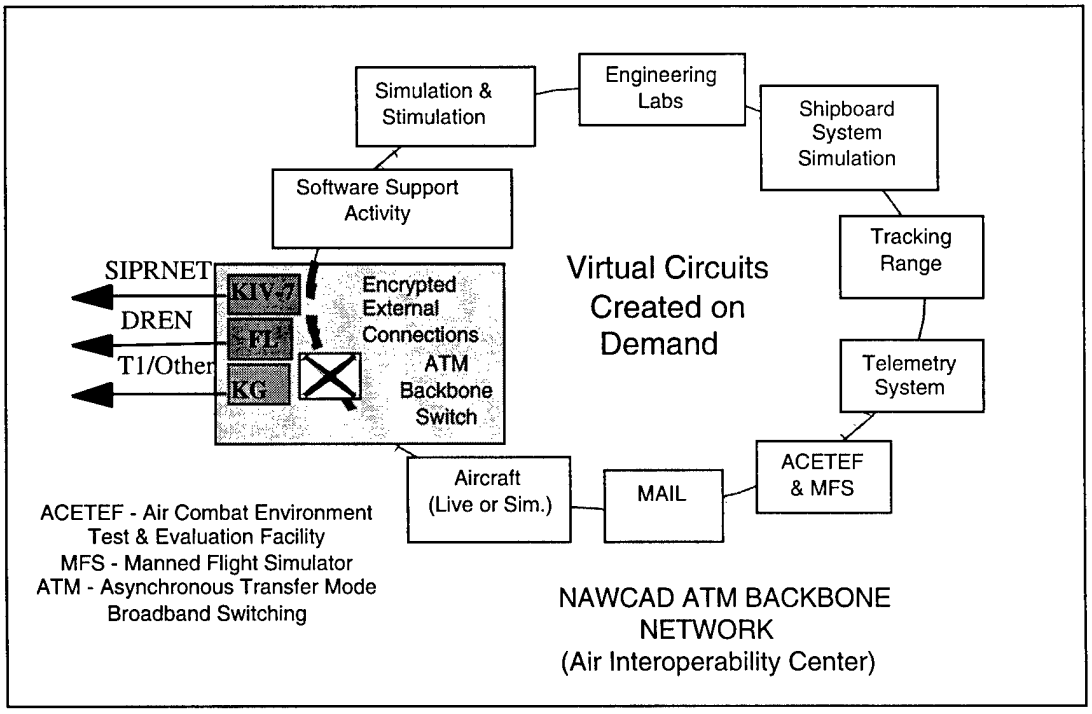

Figure 4. A Conceptual View of AIC Network Utilization

The AIC backbone network utilizes Asynchronous Transfer Mode (ATM) broadband switching. ATM is flexibly adaptable to many protocols using both real-time and non real-time engineering applications with LAN emulation and independent network control.

5.3 MAIL/MAIN Networking, Weapons Division

A number of resources at the NAWC Weapons Division (WD) have been identified for inclusion under MAIN/MAIL. These resources, both at China Lake, CA and Point Mugu, CA are listed in Table 3.

• Virtual Prototype Facility	• Inertial Development Lab
• Missile SIMLAB (IR, RF, HWIL)	• F/A-18 Weapons Syst. Support Facility
• F/A-18 Sensors Lab	• F-14 Weapons Syst. Integ. SIMLAB
• Range Control	• Missile Simulation Evaluation Lab
• Electronic Combat Range	• Data Link Lab

Table 3. Initial List of Resources for the Weapons Division (China Lake and Point Mugu) MAIL/MAIN Network

Many of the resources listed in Table 3 have been linked previously to satisfy program needs. T1 lines have been used to link resources between China Lake and Point Mugu in a number of joint simulation projects.

5.4 Demonstration Projects

A number of demonstration projects are planned to initiate MAIN/MAIL utilization. These projects will provide additional experience in linking multiple laboratory elements. The experience gained from these projects will be used to develop value added/return on investment projections for MAIN/MAIL. The following demonstrations are planned for 1998 and will be performed at the NAWC, Aircraft Division at Patuxent River, MD to demonstrate the viability of the concept. Each of the demonstrations requires additional networking between laboratories that will be provided as part of the MAIN/MAIL project.

Demonstration 1. Demonstrate Direct Coupling of Sensor Fusion Output Signals to Crew Systems Applications

This demonstration links the Information/Sensor Fusion laboratory with the Mission Computers & Processors Laboratory and with the Crewsystems laboratory. This demonstration will utilize COTS (Open System) processors to apply sensor fusion algorithms to sensor output signals and provide this information directly to the crewsystems simulators. This will allow validation of the sensor fusion algorithms and the ability of the COTS processors to handle the data. This demonstration will also provide a

more realistic crewstation simulation to resolve pilot workload and situation awareness issues

Demonstration 2. SAR Processing Directly Coupled to Crew Systems Display Lab

The Synthetic Aperture Radar (SAR) Laboratory has the capability of providing recorded "real-time" data to users as required. The data can be raw radar data as well as processed data. Utilization of a high-speed network connection will allow the data to be displayed remotely over the MAIN/MAIL networks. Networked to a series of using laboratories, SAR data can be utilized as part of a testbed for RDT&E to exercise technologies such as processors, displays and data fusion techniques. Distributed SAR data can also be applied to such applications as mission planning, battlespace awareness, intelligence, surveillance and reconnaissance.

Demonstration 3. EO/IR Lab Coupled to Crewsystems Display Lab

This demonstration will add networking between the EO/IR laboratory and the Crewsystems Display laboratory. This interconnection will enable the testing and evaluation of multi-spectral data display (combining of multi-spectral data on a single display) and sensor fusion by the combining of EO/IR and /or radar and/or LADAR data. This demonstration will also provide for the testing and demonstration of COTS hardware and operating systems to meet the needs of sensor specific signal processing algorithms on real sensor data.

Demonstration 4. Tactical Radar Lab Demonstration conducted with Industry

This demonstration will be performed under a CRADA with Northrop-Grumman Baltimore. Under the CRADA, Northrop-Grumman will provide an AN/APG-66 (F-16) radar system to the Tactical Radar laboratory at Patuxent River. The Tactical Radar laboratory will then be linked to a number of laboratories that can utilize tactical radar data. This laboratory was never intended to be networked, so the addition of external networking will add significantly to its utility. Additionally, the laboratory possesses some unique Non-Cooperative Target Identification (NCTI) processors that will interface to the AN/APG-66 radar. Under the terms of the CRADA, the radar will be available for R&D and/or the Test and Evaluation of new hardware and software components

6.0 Architecture Concepts and Issues

In 1993, the Naval Air Systems Command published a study of advanced avionics architecture and technology trends [5], [6]. One of the key findings of this study was that because of the diversity of Naval aircraft missions, a single architecture won't satisfy all applications. Although, a single architecture won't suffice, it is important that the Navy agree on a minimum number of standard architectures in order to achieve the economy of scale necessary to realize affordable avionics. As a result, system architecture is an important avionics concern. Some architectural standardization is required to effectively utilize integrated/highly modular avionics. The following sections address a number of important architecture issues, many of which are closely coupled to the effective utilization of MAIN/MAIL.

6.1 Standard Architecture Concepts

In order to achieve the economies of scale offered by standardization, it is important that standard architectural approaches be adopted where justified. Although no single architecture can satisfy all applications, if a standard development process is adopted, common tools are utilized and a core set of standard interfaces can be agreed upon, systems developed will exhibit an architectural consistency that will promote more affordable systems. It is the purpose to establish common architectures for avionics, weapons control and integration, electronic warfare suites and information systems. Through MAIN/MAIL development and utilization it is proposed to establish these common architectures and look for as much commonality as possible among the specific sub-architectures. The goal is to achieve an overall architecture of airborne electronic systems that serves to integrate avionics, flight controls and displays, EW/IS systems into a consistent architecture to emphasize commonality and minimize integration engineering issues.

The common architecture framework provides consistency in transitioning S&T products and provides a basis for more affordable common avionics systems. This architectural standardization must be coordinated with standardization activities of SAE, INCOSE and others, achieving standardization jointly with military and industry representation. A standard architectural platform will provide a reference for evaluation the suitability of COTS standards and COTS products.

6.2 Avionics Architecture Trends

For the last twenty-five years or so, military avionics systems have been characterized by use of federated systems architectures. In these systems, avionics functions have been packaged as discrete subsystems, often in separate enclosures or "black boxes". System integration has been accomplished primarily by busing together the separate sub-systems to create a complete avionics suite of equipments. The principal integration tool has been the standard aircraft multiplex data bus, in its current version MIL-Std-1553B. This bus provides the basic integration function through a "command-response" protocol. Employing, a twisted-shielded pair transmission system, MIL-Std-1553 has provided effective system integration beginning with the F-16 and continuing to current aircraft such as F-15 and F/A-18. The federated architecture has allowed avionics systems to be readily partitioned into separate sub-systems that can be separately developed as "commodities", each with an integral MIL-Std-1553B interface capability, The multiple sub-systems can then be brought together and integrated through use of the standard multiplex data bus. As a result of the predominant federated architectural approach, the Navy has created a business organization that is directly compatible. Organizationally, the commodity PMAs have been created to address the needs of important separate or discrete functional areas. An important examples is PMA-209, Air Combat Electronics which includes products in communication, navigation, information systems and flight avionics. Some other examples include PMA-233, Mission Planning; PMA-209, Aircrew Systems; and PMA-272, Electronic Warfare.

In the last ten years or so, the inadequacies of the federated architecture have become apparent. The MIL-Std-1553B data bus, primarily a control bus, has been asked to carry increasing amounts of data. Its 1 Mb/Sec bit rate is wholly inadequate for modern systems data requirements. Even for systems in which Mil-Std-1553 is retained as the control bus,

it must be supplemented by additional high-speed buses/networks to satisfy data transfer requirements. As a result of this and other trends, avionics architectures have transitioned to what is described as a modular/integrated architecture. Figure 5 provides a graphical representation of the architectural transition described.

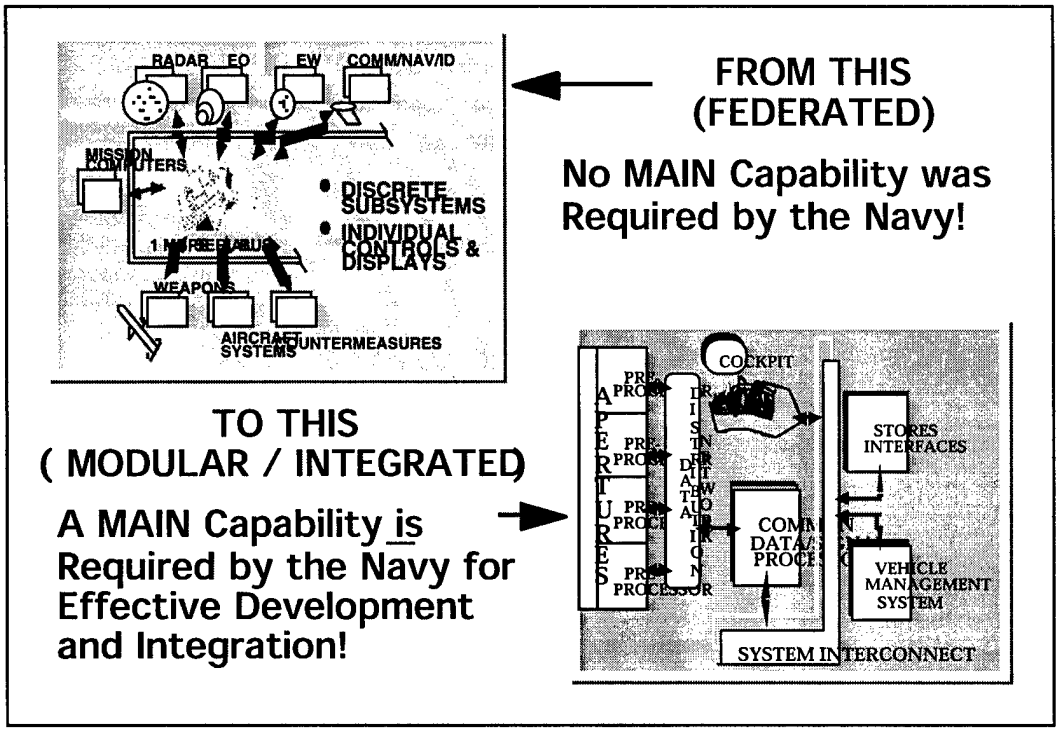

Figure 5. Graphical Representation of the Federated to Integrated Architecture Transition

As shown in Figure 5, the integrated architecture is highly modularized and consists of banks of similar processing elements. The architecture is driven by advances in microcircuit integration, which today provides processing power at a module level that once comprised a complete sub-system and required a separate electronic enclosure. Rather than utilize discrete cabling between separate sub-systems, integrated architectures rely heavily on module to module transmission lines often packaged into module backplane structures. Such systems emphasize high pin-count modular connectors with high frequency signal transmission over controlled impedance structures on the backplane. The elements of these architectures are closely coupled and highly interactive. A great deal of architectural flexibility is possible and fault tolerance/avoidance can be built in by

reallocation of resources or utilization of spare resources to minimize catastrophic failure modes.

The nature of advanced modular/integrated architectures is such that coordination between avionics commodity PMAs to agree on architectural structures, interfaces and modular standards would be very helpful. Such higher-order architectural agreement would promote a greater degree of architectural compatibility and functional interoperability between the various products of the avionics commodity PMAs. The MAIN/MAIL laboratory system provides a facility to perform the demonstrations and system integrations necessary to establish such common architectures.

6.3 System of Systems Avionics

An important role for the MAIL/MAIN is to support the integration process for advanced avionics systems. The term "system of systems" has been applied to large-scale system concepts at every level. When applied to avionics, it has come to indicate a number of major functional sub-systems integrated into a single "super-subsystem". System of systems avionics integration takes advantage of advances in microcircuit integration levels (with circuit feature sizes moving into the sub-micron level) and advances in packaging and interconnection technology. System of systems avionics integration is applicable both to new designs as well as some retrofit applications. In retrofit applications, advances in microcircuit integration allow an original sub-system enclosure to be replaced by an updated enclosure of similar volume. The internal avionics of the updated enclosure consists of an advanced modular architecture, which combines multiple functions together in the space formerly occupied by a single function. The system of systems approach is therefore particularly applicable to implement an avionics retrofit/upgrade architecture. Figure 6 illustrates the system of systems process in s flow-chart diagram form.

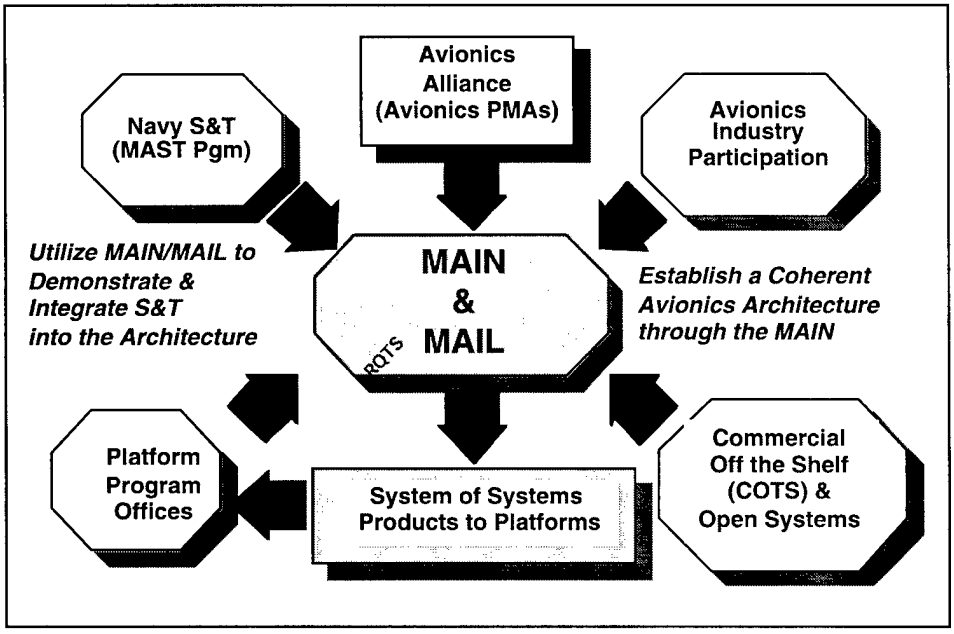

Figure 6. Avionics System of Systems Process

As shown in Figure 6, the MAIN/MAIL system can provide an integration framework to support system of systems avionics integration. As shown, the MAIN & MAIL is utilized as a development/integration laboratory under direction of the appropriate avionics PMA or jointly under several cognizant avionics PMAs representing the several avionics functional areas being integrated. Figure 6 illustrates how S&T research and technology products can be introduced and transitioned into the system of systems product. As a government laboratory resource, MAIN/MAIL allows industry to participate directly or through shared

CRADAs. Coherent system architectures can be established, integrating appropriate Open Systems/COTS products as appropriate. Coordination can be achieved between the cognizant avionics PMAs and the customer platform program offices with MAIN/MAIL providing the framework to resolve requirements issues.

7.0 Status and Future Plans

This concept that led to MAIN/MAIL implementation was first proposed in the fall of 1996. In the Spring of 1997, a leadership team was assembled from NAVAIR, NAWC Aircraft Division and NAWC Weapons Division, and the project was formally initiated, In July, 1997 a Request for Information (RFI) was issued, soliciting information regarding industry interest in the concept and desire to participate. A number of internal Navy briefings were given to develop support and initial funding for activities of the team. By use of video teleconferencing, frequent team meetings were held and activities were coordinated among the several sites. Development plans have been formulated and several preliminary steps have been completed. An assessment of available laboratory resources at the three sites has been performed and a database has been compiled. Networking planning has been initiated for the system. At Patuxent River, The AIC project has been utilized to provide the basic networking "backbone" for that site. In 1998 a number of demonstration projects have been initiated to demonstrate the potential utility of the MAIN/MAIL system.

A business plan to ensure an expanded business base for utilization of the networked laboratory system is in preparation. Preparation of a Concepts of Operations (CONOPS) guide has been initiated and will be updated and revised as the demonstration projects are completed and provide lessons learned.

As the system is demonstrated and implemented, a marketing effort will be put into place to expand the customer base. This will include a follow-up RFI to industry to initiate partnering efforts, and CRADA initiatives.

As the MAIN/MAIL system becomes operational it is expected that the activity will be made available to other elements of the AIR-4.0 Engineering Department, including AIR-4.1 Systems Engineering, AIR-4.6 Crewsystems, and AIR-4.7 Weapons as well as to AIR-5.0, Test & Evaluation.

8.0 Summary and Conclusions

This paper has provided an overview of the MAIN/MAIL initiative and its present development and implementation status. Through a discussion of its potential utilization we have attempted to place the significance of such a capability into full perspective. As discussed, MAIN/MAIL can be an important tool for the NAVAIR Avionics Department to satisfy its goal of greater coordination and unity throughout the Avionics Competency. It is expected that full implementation will provide a laboratory capability that significantly enhances the Navy's ability to conceive, prototype and fully develop and integrate the advanced avionics systems required to fulfill future missions.

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